[redacted]

APPENDIX B
COST TABLES

Cost tables are presented here for the following logies:

- o catalytic incineration
- o regenerative thermal incineration
- o nonregenerable carbon adsorption
- o regenerable fixed-bed carbon adsorption
- o absorption/stripping.

Costs were developed using the methodology given in the OAQPS Control Cost Manual (Reference 2); all costs are in 1991 dollars, unless otherwise noted in the table. All costs presented here are calculated from factored estimates, with the exception of absorption/stripping. Costs were developed for four cases:

- o 100 ppm benzene
- o 10 ppm benzene
- o 100 ppm tetrachloroethylene
- o 10 ppm tetrachloroethylene.

All these cases are for *continuous* streams and

- o OV in clean air
- o 10,000 scfm
- o 70 °F inlet temperature
- o 70 percent relative humidity
- o 70 percent heat recovery for the unit (where appropriate)
- o 95 percent destruction efficiency[1]

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[1]The destruction/removal efficiency of 95 percent was selected to represent the lower end of the range of control efficiencies required for the control of organic vapors by EPA regulations. In many cases, EPA requires higher control efficiencies especially in those situations where incineration is the technology serving as the basis of the standard. The incineration-based technolgies discussed in this document have demonstrated control efficiencies of 98 percent or higher and therefore are applicable when a higher performance standard (e.g., 98%) is required by regulation. Conducting the analysis at 95 percent as opposed to 98 percent also can impact the cost-effectiveness calculation because in many cases the additional organics control can be achieved at little or no cost. Cost-effectiveness values would therefore be lower at this higher control efficiency.

o 8,000 h/yr operation.

or absorption/stripping, insufficient information was available to distinguish any difference in capital or operating costs among the four streams and therefore the total annualized costs are independent of both the type of OV and concentration.

TABLE B-1. TOTAL ANNUALIZED COSTS FOR CATALYTIC INCINERATION FOR MODEL GAS STREAMS (100 ppm BENZENE)

Cost item	Suggested factor	Cost	Cost/unit	
Direct annualized costs, DC				
Op. Labor				
Operator	0.5 h/shift	12.96	$/h	4,630
Supervisor	15% op. labor	--		695
Maintenance				
Labor	0.5 h/shift	14.26	$/h	5,090
Materials	100% maint. labor	--		5,090
Catalyst replacement	100% replacement every 2 years	650	$/ft^3	13,000
Utilities				
Natural gas		3.30	$/kft^3	135,92
Electricity		0.06	$/kWh	1
				13,104
Total DC				177,53 0
Indirect annualized costs, IC				
Overhead	60% of sum of op., supv., and maintenance labor and maintenance materials			9,303
Admin.	2% TCI			8,394
Prop. taxes	1% TCI			4,197
Insurance	1% TCI			4,197
Capital recovery	(10%/10 years, or			

	16.275% of TCI)	68,303
Total IC		94,393
Total annualized cost (rounded)		271,923
Cost effectiveness ($/ton OV removed)		5,489

TABLE B-2. TOTAL ANNUALIZED COSTS FOR CATALYTIC INCINERATION FOR MODEL GAS STREAMS (10 ppm BENZENE)

Cost item	Suggested factor	Cost	Cost/unit	
Direct annualized costs, DC				
Op. Labor	0.5 h/shift	12.96	$/h	4,630
Operator	15% op. labor	--		695
Supervisor				
Maintenance	0.5 h/shift	14.26	$/h	5,090
Labor	100% maint. labor	--		5,090
Materials				
Catalyst replacement	100% replacement every 2 years	650	$/ft^3	13,000
Utilities		3.30	$/kft^3	138,374
Natural gas		0.06	$/kWh	
Electricity				13,104
Total DC				179,983
Indirect annualized costs, IC				
Overhead	60% of sum of op., supv., and maintenance labor and maintenance materials			9,303
Admin.	2% TCI			8,394
Prop. taxes	1% TCI			4,197
Insurance	1% TCI			4,197
Capital recovery	(10%/10 years, or 16.275% of TCI)			68,303

Total IC	94,393 274,376
Total annualized cost (rounded)	55,381
Cost effectiveness ($/ton OV removed)	

TABLE B-3. TOTAL ANNUALIZED COSTS FOR CATALYTIC INCINERATION FOR MODEL GAS STREAMS (100 ppm TETRACHLOROETHYLENE)

Cost item	Suggested factor	Cost	Cost/unit	
Direct annualized costs, DC				
Op. Labor	0.5 h/shift	12.96	$/h	4,630
Operator	15% op. labor	--		695
Supervisor				
Maintenance	0.5 h/shift	14.26	$/h	5,090
Labor	100% maint. labor	--		5,090
Materials				
Catalyst replacement	100% replacement every 2 years	650	$/ft^3	19,500
Utilities		3.30	$/kft^3	148,204
Natural gas		0.06	$/kWh	
Electricity				13,104
Total DC				196,312
Indirect annualized costs, IC				9,303
Overhead	60% of sum of op., supv., and maintenance labor and maintenance materials			8,394
Admin.	2% TCI			4,197
Prop. taxes	1% TCI			4,197
Insurance	1% TCI			
Capital recovery	(10%/10 years, or			

	16.275% of TCI)	68,303
Total IC		94,393
Total annualized cost (rounded)		290,705
Cost effectiveness ($/ton OV removed)		5,868

TABLE B-4. TOTAL ANNUALIZED COSTS FOR CATALYTIC INCINERATION FOR MODEL GAS STREAMS (10 ppm TETRACHLOROETHYLENE)

Cost item	Suggested factor	Cost	Cost/unit	
Direct annualized costs, DC				
Op. Labor				
Operator	0.5 h/shift	12.96	$/h	4,630
Supervisor	15% op. labor	--		695
Maintenance				
Labor	0.5 h/shift	14.26	$/h	5,090
Materials	100% maint. labor	--		5,090
Catalyst replacement	100% replacement every 2 years	650	$/ft^3	19,500
Utilities				
Natural gas		3.30	$/kft^3	148,96
Electricity		0.06	$/kWh	0
				13,104
Total DC				197,06 9
Indirect annualized costs, IC				
Overhead	60% of sum of op., supv., and maintenance labor and maintenance materials			9,303
Admin.	2% TCI			8,394
Prop. taxes	1% TCI			4,197
Insurance	1% TCI			4,197
Capital recovery	(10%/10 years, or			

	16.275% of TCI)	68,303
Total IC		94,393
Total annualized cost (rounded)		291,462
Cost effectiveness ($/ton OV removed)		58,829

TABLE B-5. TOTAL ANNUALIZED COSTS FOR REGENERATIVE THERMAL INCINERATION FOR MODEL GAS STREAMS (100 ppm BENZENE)[a]

Cost item	Suggested factor	Cost	Cost/unit	
Direct annualized costs, DC				
Op. Labor				
Operator	0.5 h/shift	12.96	$/h	4,630
Supervisor	15% op. labor	--		695
Maintenance				
Labor	0.5 h/shift	14.26	$/h	5,090
Materials	100% maint. labor	--		5,090
Utilities				
Fuel[b]		6.0[c]	$/h	48,000
Electricity[d]		3.36[c]	$/h	26,880
Total DC				90,385
Indirect annualized costs, IC				
Overhead	60% of sum of op., supv., and maintenance labor and maintenance materials			9,303
Admin.	2% TCI[e]			8,020
Prop. taxes	1% TCI			4,010
Insurance	1% TCI			4,010
Capital recovery	(10%/10 years, or 16.275% of TCI)			65,263
Total IC				90,606
Total annualized cost				180,991

(rounded)	
Cost effectiveness ($/ton OV removed)	3,653

[a]Thermal energy recovery is 95 percent for benzene.
[b]Based on $4/10^6$ Btu.
[c]Fuel and electrical costs provided by vendor (Pennington, 1991) in units of $/h. Costs based on 8,000 h/yr operation.
[d]Based on $0.06/kWh.
[e]TCI given by vendor (Pennington, 1991) as $401,000.

TABLE B-6. TOTAL ANNUALIZED COSTS FOR REGENERATIVE THERMAL INCINERATION FOR MODEL GAS STREAMS (10 ppm BENZENE)[a]

Cost item	Suggested factor	Cost	Cost/unit	
Direct annualized costs, DC				
Op. Labor				
Operator	0.5 h/shift	12.96	$/h	4,630
Supervisor	15% op. labor	--		695
Maintenance				
Labor	0.5 h/shift	14.26	$/h	5,090
Materials	100% maint. labor	--		5,090
Utilities				
Fuel[b]		7.0[c]	$/h	56,000
Electricity[d]		3.36[c]	$/h	26,880
Total DC				98,385
Indirect annualized costs, IC				
Overhead	60% of sum of op., supv., and maintenance labor and maintenance materials			9,303
Admin.	2% TCI[e]			8,020
Prop. taxes	1% TCI			4,010
Insurance	1% TCI			4,010
Capital recovery	(10%/10 years, or 16.275% of TCI)			65,263
Total IC				90,606
Total annualized cost				180,991

(rounded)	
Cost effectiveness ($/ton OV removed)	38,147

[a]Thermal energy recovery is 95 percent for benzene.
[b]Based on $4/10^6$ Btu.
[c]Fuel and electrical costs provided by vendor (Pennington, 1991) in units of $/h. Costs based on 8,000 h/yr operation.
[d]Based on $0.06/kWh.
[e]TCI given by vendor (Pennington, 1991) as $401,000.

TABLE B-7. TOTAL ANNUALIZED COSTS FOR REGENERATIVE THERMAL INCINERATION FOR MODEL GAS STREAMS (100 ppm TETRACHLOROETHYLENE)[a]

Cost item	Suggested factor	Cost	Cost/unit	
Direct annualized costs, DC				
Op. Labor				
Operator	0.5 h/shift	12.96	$/h	4,630
Supervisor	15% op. labor	--		695
Maintenance				
Labor	0.5 h/shift	14.26	$/h	5,090
Materials	100% maint. labor	--		5,090
Utilities				
Fuel[b]		13.0[c]	$/h	104,00
Electricity[d]		2.22[c]	$/h	0
				17,760
Total DC				137,26 5
Indirect annualized costs, IC				
Overhead	60% of sum of op., supv., and maintenance labor and maintenance materials			9,303
Admin.	2% TCI[e]			9,800
Prop. taxes	1% TCI			4,900
Insurance	1% TCI			4,900
Capital recovery	(10%/10 years, or 16.275% of TCI)			79,748
Total IC				108,65 1

Total annualized cost (rounded)	245,916
Cost effectiveness ($/ton OV removed)	4,964

[a]Thermal energy recovery is 88 percent. This is lower than for benzene in order to maintain the exhaust gas above 300 °F to minimize HCl condensation and subsequent corrosion problems.

[b]Based on $\$4/10^6$ Btu.

[c]Fuel and electrical costs provided by vendor (Pennington, 1991) in units of $/h. Costs based on 8,000 h/yr operation.

[d]Based on $0.06/kWh.

[e]Given by vendor (Pennington, 1991) as $490,000.

TABLE B-8. TOTAL ANNUALIZED COSTS FOR REGENERATIVE THERMAL INCINERATION FOR MODEL GAS STREAMS (10 ppm TETRACHLOROETHYLENE)[a]

Cost item	Suggested factor	Cost	Cost/unit	
Direct annualized costs, DC				
Op. Labor				
Operator	0.5 h/shift	12.96	$/h	4,630
Supervisor	15% op. labor	--		695
Maintenance				
Labor	0.5 h/shift	14.26	$/h	5,090
Materials	100% maint. labor	--		5,090
Utilities				
Fuel[b]		13.8[c]	$/h	110,400
Electricity[d]		2.2[c]	$/h	17,760
Total DC				143,665
Indirect annualized costs, IC				
Overhead	60% of sum of op., supv., and maintenance labor and maintenance materials			9,303
Admin.	2% TCI[e]			9,800
Prop. taxes	1% TCI			4,900
Insurance	1% TCI			4,900
Capital recovery	(10%/10 years, or 16.275% of TCI)			79,748
Total IC				108,651

Total annualized cost (rounded)	252,316
Cost effectiveness ($/ton OV removed)	50,928

[a]Thermal energy recovery is 88 percent. This is lower than for benzene in order to maintain the exhaust gas above 300 °F to minimize HCl condensation and subsequent corrosion problems.
[b]Based on $\$4/10^6$ Btu.
[c]Fuel and electrical costs provided by vendor (Pennington, 1991) in units of $/h. Costs based on 8,000 h/yr operation.
[d]Based on $0.06/kWh.
[e]Given by vendor (Pennington, 1991) as $490,000.

TABLE B-9. TOTAL ANNUALIZED COSTS FOR NONREGENERABLE CARBON ADSORPTION FOR MODEL GAS STREAMS (100 ppm BENZENE)

Cost item	Suggested factor	Cost	Cost/unit	
Direct annualized costs, DC				
Op. Labor				
Operator	0.5 h/shift	12.96	$/h	4,630
Supervisor	15% op. labor	--		695
Maintenance				
Labor	0.5 h/shift	14.26	$/h	5,090
Materials	100% maint. labor	--		5,090
Carbon regeneration	1.5 E6 lb/yr	0.80	$/lb	1,233,800
Electricity	13.5 kW[a]	0.06	$/kWh	6,500
Total DC				1,255,805
Indirect annualized costs, IC				
Overhead	60% of sum of op., supv., and maintenance labor and maintenance materials			9,303
Admin.	2% TCI			1,952
Prop. taxes	1% TCI			976
Insurance	1% TCI			976
Capital recovery	(10%/10 years, or 16.275% of TCI)			15,884
Total IC				29,091
Total annualized				1,284,8

cost (rounded)	96
Cost effectiveness ($/ton OV removed)	25,935

[a]Based on 7 in. H_2O pressure drop for fan. Electricity for the fan is the only cost accounted for here.

TABLE B-10. TOTAL ANNUALIZED COSTS FOR NONREGENERABLE CARBON ADSORPTION FOR MODEL GAS STREAMS (10 ppm BENZENE)

Cost item	Suggested factor	Cost	Cost/unit	
Direct annualized costs, DC				
Op. Labor				
Operator	0.5 h/shift	12.96	$/h	4,630
Supervisor	15% op. labor	--		695
Maintenance				
Labor	0.5 h/shift	14.26	$/h	5,090
Materials	100% maint. labor	--		5,090
Carbon regeneration	2.5 E5 lb/yr	0.80	$/lb	197,000
Electricity	5.6 kW[a]	0.06	$/kWh	2,700
Total DC				215,205
Indirect annualized costs, IC				
Overhead	60% of sum of op., supv., and maintenance labor and maintenance materials			9,303
Admin.	2% TCI			1,630
Prop. taxes	1% TCI			815
Insurance	1% TCI			815
Capital recovery	(10%/10 years, or 16.275% of TCI)			13,264
Total IC				25,827
Total annualized				241,031

cost (rounded)	
Cost effectiveness ($/ton OV removed)	48,650

[a]Based on 2.9 in. H_2O pressure drop for fan. Electricity for the fan is the only cost accounted for here.

TABLE B-11. TOTAL ANNUALIZED COSTS FOR NONREGENERABLE CARBON ADSORPTION FOR MODEL GAS STREAMS (100 ppm TETRACHLOROETHYLENE)

Cost item	Suggested factor	Cost	Cost/unit	
Direct annualized costs, DC				
Op. Labor				
Operator	0.5 h/shift	12.96	$/h	4,630
Supervisor	15% op. labor	--		695
Maintenance				
Labor	0.5 h/shift	14.26	$/h	5,090
Materials	100% maint. labor	--		5,090
Carbon regeneration	1.2 E6 lb/yr	0.80	$/lb	942,000
Electricity	10.2 kW[a]	0.06	$/kWh	5,400
Total DC				962,905
Indirect annualized costs, IC				
Overhead	60% of sum of op., supv., and maintenance labor and maintenance materials			9,303
Admin.	2% TCI			1,856
Prop. taxes	1% TCI			928
Insurance	1% TCI			928
Capital recovery	(10%/10 years, or 16.275% of TCI)			15,103
Total IC				28,118
Total annualized				991,022

cost (rounded)	
Cost effectiveness ($/ton OV removed)	20,003

[a]Based on 5.8 in. H_2O pressure drop for fan. Electricity for the fan is the only cost accounted for here.

TABLE B-12. TOTAL ANNUALIZED COSTS FOR NONREGENERABLE CARBON ADSORPTION FOR MODEL GAS STREAMS (10 ppm TETRACHLOROETHYLENE)

Cost item	Suggested factor	Cost	Cost/unit	
Direct annualized costs, DC				
Op. Labor				
Operator	0.5 h/shift	12.96	$/h	4,630
Supervisor	15% op. labor	--		695
Maintenance				
Labor	0.5 h/shift	14.26	$/h	5,090
Materials	100% maint. labor	--		5,090
Carbon regeneration	1.6 E5 lb/yr	0.80	$/lb	128,300
Electricity	5.2 kW[a]	0.06	$/kWh	2,500
Total DC				146,305
Indirect annualized costs, IC				
Overhead	60% of sum of op., supv., and maintenance labor and maintenance materials			9,303
Admin.	2% TCI			1,612
Prop. taxes	1% TCI			806
Insurance	1% TCI			9806
Capital recovery	(10%/10 years, or 16.275% of TCI)			13,118
Total IC				25,644
Total annualized				171,949

cost (rounded)	
Cost effectiveness ($/ton OV removed)	34,707

[a]Based on 2.7 in. H_2O pressure drop for fan. Electricity for the fan is the only cost accounted for here.

TABLE B-13. TOTAL ANNUALIZED COSTS FOR REGENERABLE FIXED BED CARBON ADSORPTION FOR MODEL GAS STREAMS (100 ppm BENZENE)

Cost item	Suggested factor	Cost	Cost/unit	
Direct annualized costs, DC				
Op. Labor				
Operator	0.5 h/shift	12.96	$/h	4,630
Supervisor	15% op. labor	--		695
Maintenance				
Labor	0.5 h/shift	14.26	$/h	5,090
Materials	100% maint. labor	--		5,090
Carbon regeneration (Steam + cooling water)	1.56 E6 lb/yr	8.23	$/1000lb	12,700
Carbon replacement	5 yr carbon bed life. 5% loss in regen.	2	$/lb	17,600
Electricity	13.5 kW[a]	0.06	$/kWh	6,500
Total DC				52,305
Indirect annualized costs, IC				
Overhead	60% of sum of op., supv., and maintenance labor and maintenance materials			9,303
Admin.	2% TCI			3,676
Prop. taxes	1% TCI			1,838
Insurance	1% TCI			1,838
Capital recovery	(10%/10 years, or 16.275% of TCI)			29,913
Total IC				46,568

Total annualized cost (rounded)	98,873
Cost effectiveness ($/ton OV removed)	1,996

[a]Based on 7.0 in. H_2O pressure drop for fan. Electricity for the fan is the only cost accounted for here.

TABLE B-14. TOTAL ANNUALIZED COSTS FOR REGENERABLE FIXED BED CARBON ADSORPTION FOR MODEL GAS STREAMS (10 ppm BENZENE)

Cost item	Suggested factor	Cost	Cost/unit	
Direct annualized costs, DC				
Op. Labor				
Operator	0.5 h/shift	12.96	$/h	4,630
Supervisor	15% op. labor	--		695
Maintenance				
Labor	0.5 h/shift	14.26	$/h	5,090
Materials	100% maint. labor	--		5,090
Carbon regeneration (Steam + cooling water)	2.5 E5 lb/yr	8.23	$/1000lb	2,000
Carbon replacement	5 yr carbon bed life. 5% loss in regen.	2	$/lb	2,800
Electricity	5.6 kW[a]	0.06	$/kWh	2,700
Total DC				23,005
Indirect annualized costs, IC				
Overhead	60% of sum of op., supv., and maintenance labor and maintenance materials			9,303
Admin.	2% TCI			2,840
Prop. taxes	1% TCI			1,420
Insurance	1% TCI			1,420
Capital recovery	(10%/10 years, or 16.275% of TCI)			23,111
Total IC				38,093

Total annualized cost (rounded)	61,098
Cost effectiveness ($/ton OV removed)	12,332

[a]Based on 2.9 in. H_2O pressure drop for fan. Electricity for the fan is the only cost accounted for here.

TABLE B-15. TOTAL ANNUALIZED COSTS FOR REGENERABLE FIXED BED CARBON ADSORPTION FOR MODEL GAS STREAMS (100 ppm TETRACHLOROETHYLENE)

Cost item	Suggested factor	Cost	Cost/unit	
Direct annualized costs, DC				
Op. Labor				
Operator	0.5 h/shift	12.96	$/h	4,630
Supervisor	15% op. labor	--		695
Maintenance				
Labor	0.5 h/shift	14.26	$/h	5,090
Materials	100% maint. labor	--		5,090
Carbon regeneration (Steam + cooling water)	1.2 E6 lb/yr	8.23	$/1000lb	9,700
Carbon replacement	5 yr carbon bed life. 5% loss in regen.	2	$/lb	13,500
Electricity	10.2 kW[a]	0.06	$/kWh	5,400
Total DC				44,105
Indirect annualized costs, IC				
Overhead	60% of sum of op., supv., and maintenance labor and maintenance materials			9,303
Admin.	2% TCI			3,432
Prop. taxes	1% TCI			1,716
Insurance	1% TCI			1,716
Capital recovery	(10%/10 years, or 16.275% of TCI)			27,928
Total IC				44,095

Total annualized cost (rounded)	88,199
Cost effectiveness ($/ton OV removed)	1,780

[a]Based on 5.8 in. H_2O pressure drop for fan. Electricity for the fan is the only cost accounted for here.

TABLE B-16. TOTAL ANNUALIZED COSTS FOR REGENERABLE FIXED BED CARBON ADSORPTION FOR MODEL GAS STREAMS (10 ppm TETRACHLOROETHYLENE)

Cost item	Suggested factor	Cost	Cost/unit	
Direct annualized costs, DC				
Op. Labor				
Operator	0.5 h/shift	12.96	$/h	4,630
Supervisor	15% op. labor	--		695
Maintenance				
Labor	0.5 h/shift	14.26	$/h	5,090
Materials	100% maint. labor	--		5,090
Carbon regeneration (Steam + cooling water)	1.65 E5 lb/yr	8.23	$/1000lb	1,300
Carbon replacement	5 yr carbon bed life. 5% loss in regen.	2	$/lb	1,800
Electricity	5.2 kW[a]	0.06	$/kWh	2,500
Total DC				21,105
Indirect annualized costs, IC				
Overhead	60% of sum of op., supv., and maintenance labor and maintenance materials			9,303
Admin.	2% TCI			2,792
Prop. taxes	1% TCI			1,396
Insurance	1% TCI			1,396
Capital recovery	(10%/10 years, or 16.275% of TCI)			22,720
Total IC				47,607

Total annualized cost (rounded)	58,711
Cost effectiveness ($/ton OV removed)	11,850

[a]Based on 2.7 in. H_2O pressure drop for fan. Electricity for the fan is the only cost accounted for here.

TABLE B-17. TOTAL ANNUALIZED COSTS FOR QVF ABSORPTION PROCESS FOR MODEL GAS STREAMS

Cost item	Suggested factor	Cost	Cost/unit	
Direct annualized costs, DC				
Op. Labor				
Operator	0.5 h/shift	12.96	$/h	4,630
Supervisor	15% op. labor	--		695
Maintenance				
Labor	0.5 h/shift	14.26	$/h	5,090
Materials	100% maint. labor	--		5,090
Utilities				960
Cooling water		0.40	$/1,000 ft^3	8,826
Electricity		0.06	$/kWh	
Total DC				25,291
Indirect annualized costs, IC				
Overhead	60% of sum of op., supv., and maintenance labor and maintenance materials			9,303
Admin.	2% TCI[a]			30,200
Prop. taxes	1% TCI			15,100
Insurance	1% TCI			15,100
Capital recovery	(10%/10 years, or 16.275% of TCI)			245,753
Total IC				306,153
Total annualized cost[b] (rounded)				331,400

Cost effectiveness ($/ton OV removed)	1,996
100 ppm benzene	6,700
10 ppm benzene	66,900
100 ppm tetrachloroethylene	3,300
10 ppm tetrachloroethylene	32,800

[a]TCI is taken as $1.51 million as discussed in Section 5.0.
[b]TAC is the same for all model gas streams.